# Integrated radiation and hygienic approach to production safety. assessment of the impact on public health

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**Abstract**

The development of uranium-plutonium compounds as nuclear fuel is a new nuclear technology using little-studied highly active uranium compounds. The toxicity and biological effects of such compounds are the subject of this report. It should be noted that during the production of MNUP fuel there is a possibility of impact on the population and the environment, which is mainly due to the involvement of plutonium in the nuclear fuel cycle, since it is more radiation hazardous than uranium. The report devoted to this work discusses the multifactorial impact of the components of the MNUP fuel on public health: external photon and neutron exposure and internal exposure due to inhalation intake of 238U, 239Pu and their decay products. Based on the presented data, a scientifically based approach to assessing the impact of factors of the components of the MNUP fuel on the health of the population is proposed. To develop this science-based approach, the results of the analysis of the available experimental assessments of the toxicity of radionuclides and their compounds that are part of the MNUP fuel and the results of our own research by the personnel of the production of MNUP fuel were used. The method used in the work for assessing the health indicators of the population living in close proximity to enterprises working with MNUP fuel will make it possible to offer recommendations for doctors who monitor the state of public health.

## INTRODUCTION

It is important and relevant to assess the risk of the impact of production factors for the production of MNUP fuel on public health. It should be noted that until now, in the system of monitoring the health of personnel of radiation-hazardous industries, the indicator of general morbidity is not used in assessing occupational morbidity due to production. The problem of using general morbidity to assess the impact of production factors on the health of workers has become especially relevant with the development of new technologies for producing nuclear fuel and the need to ensure radiation protection of workers. In Russia in 2010, a large-scale program was launched to transfer the country's nuclear energy to a new technological platform - the transfer of nuclear power plants operating on thermal neutrons to fast neutrons with a closed nuclear fuel cycle. Currently, within the framework of the Breakthrough project area, new technologies are being developed for the fabrication and refabrication of mixed uranium-plutonium (MNUP) fuel. In this paper, to assess the health status of the personnel of the experimental production of MNUP fuel, an indicator of general morbidity is proposed, and for a quantitative assessment, a risk assessment method is proposed. In the medical aspect, morbidity is an integral indicator of the health of both an individual and a group of people as a whole. In the general biological aspect, morbidity is an integral indicator of the reactivity and resistance of the body to the effects of negative environmental factors that determine the functional state of the body, regulated by the hormones of the neuroendocrine system. In the aspect of radiation protection, morbidity is an indicator of the tissue effects of radiation exposure, which can be controlled at the level of the functional state of individual organs and body systems.

## results of research and their analysis

The existing system of radiation protection in the field of human health is aimed at preventing deterministic (tissue) effects and minimizing the risks of stochastic effects. The practical basis of human radiation protection is the measurement and evaluation of doses. The main dose limits established in the national radiation safety standards NRB-99/2009 ensure radiation safety for personnel under conditions of regulated (normal) operation of the radiation source [1].

Based on these provisions, the main attention in assessing the health of workers in radiation-hazardous industries is paid to identifying long-term radiation effects (oncological morbidity), and in scientific research - to assessing the risk of oncological morbidity.

However, at radiation-hazardous enterprises, along with the main hazard factor - radiation, the human body is influenced by other harmful factors of a physical and chemical nature that accompany radiation production. In each production, the combination of these factors is different and, therefore, the consequences of their impact on the human body are different [2].

The impact of combined factors on the human body is different at different times after the start of contact. Due to the slow implementation of the dose from most radionuclides and the rapid impact of chemicals, they are the leading in action on the body in the initial period of exposure. In later periods and, especially, in the remote period of sensitization of the body to chemicals, the body reacts differently to irradiation.

Long-term effects of radiation develop against the background of altered health. The use of nitride uranium-plutonium compounds as nuclear fuel is a new nuclear technology, the implementation of which causes a number of dangerous factors, the impact of which on humans has not yet been sufficiently studied.

During the preparation of TVEL (fuel element) compositions of MNUP fuel, inhalation intake of radioactive uranium-plutonium compounds into the body of personnel takes place, which is confirmed by the presence of 238U, 239Pu, 241Am in urine samples. The fact that uranium-plutonium nitride compounds enter the body of personnel, mainly in the form of sparingly soluble aerosols of varying degrees of dispersion, has been revealed. The coarse fraction makes up 76–86% of the total volumetric activity of the compounds, and 14–24% contribution to the volumetric activity is made by finely dispersed aerosols less than 200–400 nm in size, which indicates the presence of radioactive nanoparticles, the toxicity of which is much higher than that of macroparticles [2].

Analysis of the radionuclide composition of these aerosols showed that the main dose-forming radionuclide is 239Pu. Its contribution to volumetric activity is 80% of all activity. Estimates of external exposure doses due to γ-nitron exposure, the annual individual equivalent doses of which are 2.1 ± 0.4 mSv per year of radiation and 0.4 ± 0.1 mSv per year of neutron radiation, including the lens of the eye - 2 .3 ± 0.5 mSv per year, facial skin 2.7 ± 0.6 mSv per year, gonads - 3.4 ± 1.3 mSv per year and skin of the hands - 190.0 ± 50.0 mSv per year. At the same time, there is still no data on internal exposure doses and on possible other routes of entry (through the skin, orally) of these compounds into the body of personnel, and the degree of their danger from intake by these routes has not been assessed.

In addition, the nitride compounds 239Pu and 238U have not been used in industry so far. Their toxic effects have not been studied. The presented actual data indicate that the personnel of the experimental production for the manufacture of TVEL compositions of MNUP-fuel work under the conditions of complex exposure to insufficiently studied sources of ionizing radiation. A study of the health status of 50 workers in the experimental production of MNUP fuel (according to the general medical examination of the population) revealed a relatively high incidence of general morbidity, amounting to 1064.5±65.5 diseases per 1000 workers per year. Comparison of the observed frequency and peculiarities of the structure of morbidity of workers in the production of MNUP fuel with radiation doses clearly reveals that the effective dose of 4.6 mGy per year cannot be the only reason for the high morbidity of workers in complex radiochemical production. The radiation dose characterizes only the influence of one of the many factors of production that affect the body of workers. A study of the health status of 50 workers in the experimental production of MNUP fuel according to the data presented in the Health Passport. The available published data of clinical observations show that the main changes under the influence of sparingly soluble Pu compounds occur in the lungs at radiation doses of 150 mGy to the lungs and are manifested by a slight decrease in VC (lung capacity), detected in group studies. The presented data show that the existing system for assessing the impact of production factors on the health of workers, based on monitoring only the radiation factor, is not adequate to the impact of complex factors of radiochemical production. New approaches are needed to assess the health of workers in complex, highly dangerous new technologies for the production of nuclear fuel, which is an integral indicator of health that characterizes the "morbidity" of both an individual and a team as a whole. It is obvious that morbidity is an adequate indicator of harmful factors of production on the health of workers. The need to take medical measures to protect the health of personnel involved in work with MNUP fuel determines the relevance of solving the following tasks: Assessment of the frequency and structure of primary, chronic and general morbidity among workers in the experimental production of MNUP fuel; Comparative studies of the morbidity of workers in the production of MNUP-fuel and workers in other industries of the nuclear fuel complex in order to identify the characteristics of the incidence of workers in MNUP-fuel; Assessment of the influence of production factors on the incidence of workers in the production of MNUP fuel; Development of recommendations for monitoring the health status of workers in the production of MNUP-fuel in order to early identify possible occupational diseases. An important factor in solving the tasks set is the scientifically based choice of methods and criteria for assessing the incidence and statistical reliability of the assessment of the results. In this paper, estimates of the relative risk of the impact of the production factor on the incidence of workers were made on the basis of a comparative analysis of the overall incidence of workers in the production of MNUP fuel and workers of the KhMZ (chemical and metallurgical plant) and RHZ (radiochemical plant) SCC (Siberian Chemical Combine) (RRmnup/khmz=1.28 and RRmnup/rkhz = 0.84). Radiation risk assessments were made on the basis of a comparative analysis of the morbidity of organs and systems "critical" to the effects of radiation of workers in the production of MNUP fuel and workers of the KhMZ and RCP of the SCC and do not have dose confirmation. The available estimates of exposure doses for workers in the MNUP fuel - the equivalent dose of external exposure, which is 2.4 mSv per year and the dose of internal exposure equal to the dose of external exposure, totaling effective dose = 4.5 mSv per year [5], cannot be the reason for the high morbidity of workers, since they do not exceed the established exposure dose limits for workers (group A personnel of radiation hazardous industries - 20 mSv per year on average for any consecutive five years, but not more than 50 mSv per year). Experts [5] believe that the complex morphological and dispersed composition of MNUP fuel particles in combination with the complex chemical composition caused by aerosol aging processes can lead to a fundamental difference between the processes of MNUP aerosols and, consequently, the degree of radiation hazard from those accepted in the ICRP models for uranium and plutonium [5]. The proposed algorithm of the system for monitoring the health of workers in the production of MNUP fuel makes it possible to strengthen the existing system of radiation protection.

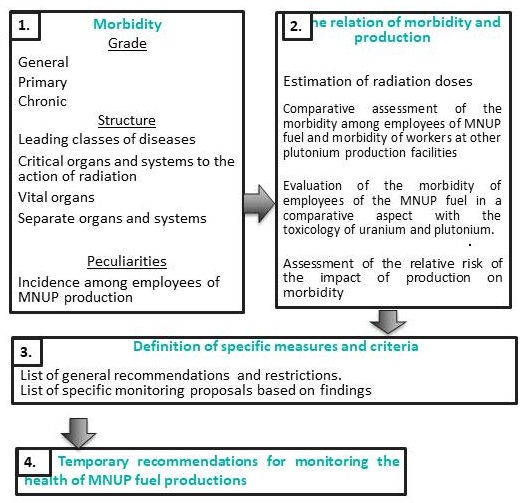


Figure 1 ¬ Algorithm for medical supervision of personnel experimental production of MNUP fuel.

## CONCLUSION

1. 1. An algorithm for a system for monitoring the health of workers in a mixed uranium-plutonium production is proposed.
2. 2. It is expedient to use the proposed algorithm for assessing the health status of the population living near the enterprise for the production of MNUP fuel.
3. 3. The impact of the production of MNUP fuel on health is of a multi-organ, poly-system nature, corresponding to the distribution of uranium in the body.
4. 4. The impact of the production of MNUP fuel has a damaging effect on the resistance (immunity) of the body.
5. 5. In assessing the impact of the production factors of the MNUP of production on the incidence of workers, the radiation risk is of decisive importance.

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